Third Molar Formation And Its Development Course

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The mandibular third molar is an unusual tooth characterized by considerable variability in formation timing, variations in crown and root morphology and, not infrequently, by agenesis. Most studies of the mandibular third molar have been concerned with its presence or absence, or with differences in size and morphology. In recent years, however, increased investigative attention has been devoted to the calcification and movement of the mandibular third molar. Thus, Banks[1] investigated calcification timing of this tooth in Denver orthodontic patients; Saito[21] studied calcification of the third molar in Japanese; Demisch and Wartmann[4] explored the relationship between successive third molar formation stages and skeletal age; and Björk, Jensen and Palling[2] reported on third molar calcification timing in relation to its subsequent eruptive course.

These studies, however, were largely concerned with cross-sectional material, and the analyses were therefore cross-sectional in execution. Questions of constancy of third molar formation, the relationships between third molar calcification and movement, and interrelationships between dental development and somatic maturation were thus left open for further study.

The present report, therefore, is concerned with long-term studies of third molar calcification and movement in the same group of children. Of particular interest are the questions of constancy of developmental status (over a twelve-year period), interrelationships between calcification and movement timing within individuals, and relationships with various measures of physical maturation.

METHODS AND MATERIALS

The present study is based upon serial, longitudinal oblique-jaw and lateral-head radiographs of 140 clinically-healthy, Ohio-born white participants in the Fels Longitudinal Studies of Growth and Development.[9] The head and jaw radiographs were supplemented by serial postero-anterior radiographs of the lower leg and hand to determine the time of osseous completion. Data on sexual maturation, in turn, came from the Fels Longitudinal Records.

In analyzing the developmental course of the mandibular third molar tooth, a total of nine stages of calcification and movement were recognized, as shown in Figure 1. This number of stages was chosen in contrast to the smaller number of developmental stages previously recognized by us [12,19] in order to take maximum advantage of the unusually long developmental course of the mandibular third molar tooth. For each child in the series, the earliest age at which each stage of third molar development had been attained was recorded as the "age-at-attainment." Cumulative frequency curves were then drawn from the recorded ages at attainment, and the 15th, 50th, and 85th percentiles were determined by interpolation from the curves as we have pre-

viously described. [12,19]

The timing of osseous maturation was determined, for each child in the study, as (1) the age of union of the proximal epiphysis of the tibia, i.e., tibial union,[16] and (2) the age at complete union of all epiphyses of the metacarpals and digits, i.e., hand completion.[14] In addition to these objective measures of osseous union in the appendicular skeleton, which eliminated the necessity of estimating "bone ages" from pictorial standards, menarcheal data were obtained for the girls in this series from the serial longitudinal health histories maintained at the Fels Research Institute for the past thirty years.[9]

In the correlational studies, all "raw" scores for ages at attainment were converted into normalized sex-specific T-scores using McCall's method.[9,18] This normalizing procedure not only simplified computation, but also eliminated

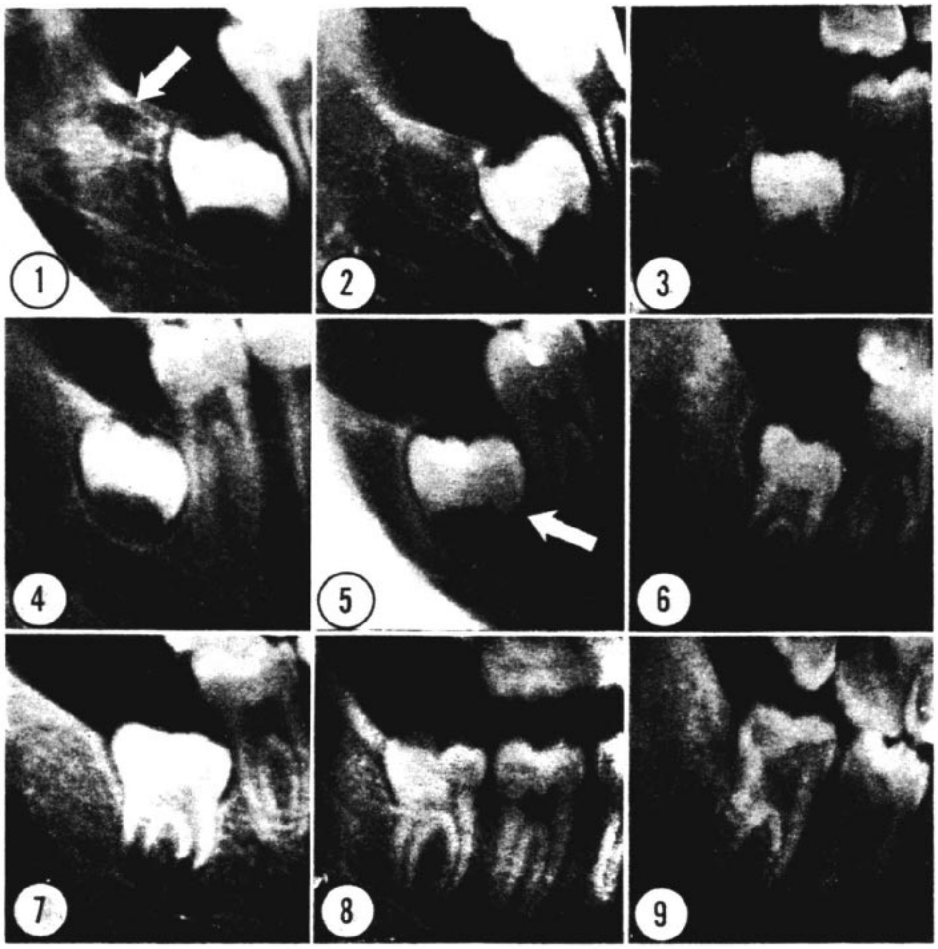

Fig. 1 Formation stages of the mandibular third molar tooth. 1) small follicle, 2) full follicle, 3) cusp calcification, 4) crown completion (without root formation), 5) root formation, 6) half root, 7) alveolar eruption, 8) molar cusp level, 9) apical completion. Throughout the present study the age-at-attainment of each of these stages was recorded as the earliest age at which the rating criterion was radiographically visible.

skewness and made practical the pooling of male and female data in the final correlations. The forty intercorrelations for tooth development and the fifty-four correlations involving second and third molar development and physical maturation were completed with the aid of an IBM 602 calculator.

Since the relationship between third molar development and somatic maturation was based entirely on intrachild comparisons, the problem of sampling did not enter into consideration. Secular trends, moreover, could be neglected in this study, as a preliminary survey showed. However, it may be valuable to further define the subject population as being almost exclusively of northwest European origin, and largely of the lower-middle, and middle-middle economic and social classes as defined either by indexes of parental education, or by multiple indexes of occupation, housing and economic achievement.

Findings

As shown in Table I, where values for the age-at-appearance of nine stages of third molar formation are set forth, this tooth develops over a long time period. M_3 first shows evidence of follicle formation during the eighth year on the average, but apical closure is not complete until the twentieth year of life. And, in a substantial number of cases, the third molar tooth requires even more than twelve years to complete its formation, often being still incomplete well after the time of legal majority.

Interestingly enough, and unlike any other permanent tooth we have studied to date, [15] the mandibular third molar evidenced no meaningful sex difference throughout its developmental course. For all nine stages of formation and movement considered in this paper, sex differences were not statistically significant throughout. Moreover, the general tendency was for the girls to be later than the boys in third molar formation. Under these circumstances, male and female data on formation of the mandibular third molar may be combined, as shown in the combined-sex percentiles of Table I.

Since the mandibular third molar tooth has long been famous for its vari-

TABLE I

SEX DIFFERENCE, PERCENTILES AND VARIABILITY IN THIRD MOLAR DEVELOPMENT

Stage of Development	Median Age (Years)		Combined-Sex Percentiles				
	Boys	Girls	N	15	50[1]	85	"Variability[2]"
1. Small Follicle	8.7	8.6	70	7.7	8.6	10.2	15
2. Full Follicle	9.2	9.1	90	8.1	9.1	10.2	12
3. Cusp Calcification	9.4	9.6	140	8.3	9.4	10.8	14
4. Crown Completion	13.6	14.2	79	12.4	13.9	16.0	13
5. Root Formation	14.4	15.0	66	13.3	14.8	16.7	12
6. Half Root	16.7	17.2	95	15.4	16.9	17.9	8
7. Alveolar Eruption	16.9	17.1	94	15.9	17.0	17.9	6
8. Cusp Level	17.9	17.8	39	17.2	17.8		14
9. Apical Completion	20.2	19.9	37	17.7	20.0		13

[1]Median

[2]Calculated as the difference between the 15th and 85th percentiles divided by twice the median.

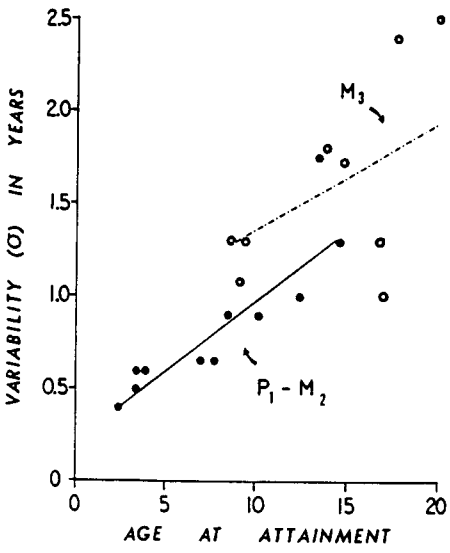

Fig. 2 Comparative variability of nine stages of third molar formation (white dots) and calcification stages of the remaining posterior teeth (black dots). Although variability of formation and eruption of the mandibular third molar is absolutely greater than that of the remaining teeth, the difference is largely eliminated when corrected for the mean age-at-attainment.

ability in formation timing, data on this aspect were compared with variability data on the remaining posterior teeth (Figure 2). Clearly, on an absolute basis, the mandibular third molar tooth is more variable than other molar or premolar teeth of the lower jaw. But, as shown by the two trend lines on the second figure, variability of the mandibular third molar is not markedly greater than that of other teeth when expressed in relationship to the mean age-at-attainment of the particular formation stages in question. As with P_1, P_2, M_1 and M_2, variability of the third molar increases directly with mean age-at-attainment, and the absolutely large variability of the mandibular third molar tooth is thus almost completely explained as part of a general biological trend.

As shown in Table II, where intercorrelations in third molar development are summarized for all nine stages considered in this study, this tooth shows considerable communality within itself. Early third molar formation at one stage is associated with early formation at another stage and vice versa. Expectably, stages of third molar formation that are closely related in time (as for example, the small-follicle and full-follicle stages) are characterized by the highest intercorrelations, exceeding in many cases 0.9. On the other hand, stages of third molar formation most remote in time, as in the two follicle

TABLE II

INTERCORRELATIONS IN THIRD MOLAR DEVELOPMENT

Stage of Development	1 S.f.	2 F.f.	3 C.c.	4 Cr.c.	5 R.f.	6 H.r.	7 A.e.	8 C.l.	9 A.c.
1. Small Follicle (S.f.)		0.96	0.95	0.82	0.73	0.58	0.48	0.50[1]	0.33
2. Full Follicle (F.f.)			0.96	0.79	0.67	0.68	0.64	0.34	0.81
3. Cusp Calcification (C.c.)				0.75	0.76	0.60	0.56	0.44	0.26
4. Crown Completion (Cr.c)					0.90	0.70	0.62	-[2]	-[2]
5. Root Formation (R.f.)						0.82	0.64	-[2]	-[2]
6. Half Root (H.r.)							0.83	0.50	0.57
7. Alveolar Eruption (A.e.)								0.45	0.33
8. Cusp Level (C.l.)									0.76
9. Apical Completion (A.c.)									

[1] Small sample N = 10-15.

[2] N less than 10.

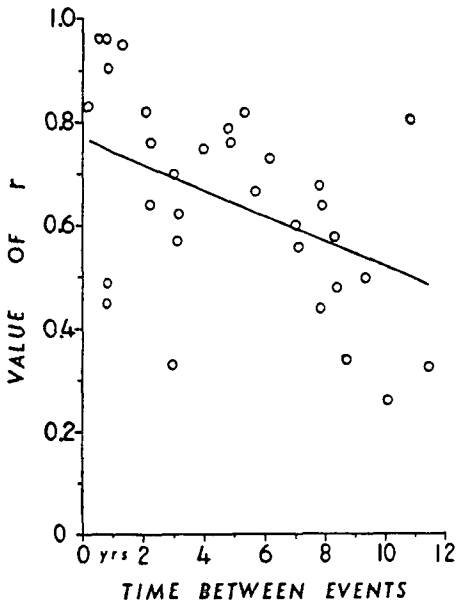

Fig. 3 Constancy of third molar formation timing. As shown in this figure intrastage correlations in third molar formation range as high as 0.96 for events occurring less than one year apart, and range downward to 0.3 for developmental events separated by as much as twelve years. The third molar tooth shows considerably higher constancy during its developmental course than teeth previously investigated (cf. Garn, Lewis and Polacheck[12]).

stages and attainment of cusp level or apical completion, show lower mean intercorrelations averaging 0.4-0.5. This tendency for interrelationships to decrease in magnitude with elapsed time is further depicted in Figure 3 where the correlation coefficients are set forth in relation to the mean time between developmental events. Notably, the third molar tooth not only shows high short-term intercorrelations but surprisingly high intercorrelations throughout: even after twelve years have elapsed, stages of third molar formation have much more in common than was previously observed for the other mandibular molar and premolar teeth.[12]

Relating third molar formation for all nine stages involved to three measures of somatic and sexual maturation, it is clear that the mandibular third molar is but slightly correlated with these other developmental events (Table III). With menarche, the customary measure of sexual maturation in females, correlations are low and not statistically significant. With tibial union (union of the proximal epiphysis of the tibia to the diaphysis)[16] and hand

TABLE III

CORRELATIONS BETWEEN THIRD MOLAR DEVELOPMENT AND PHYSICAL MATURATION IN BOYS AND GIRLS

Stage of M_3 Development	Menarche N	Menarche *r*	Tibial Union[1] N	Tibial Union[1] *r*	Hand Union[2] N	Hand Union[2] *r*
			Correlations			
1. Small Follicle	37	-0.02	48	0.28[3]	35	0.37[3]
2. Full Follicle	40	0.06	59	0.13	46	0.27
3. Cusp Calcification	64	0.07	94	0.14	72	0.28[3]
4. Crown Completion	36	0.24	50	0.36[3]	36	0.41[3]
5. Root Formation	38	0.05	48	0.39[3]	25	0.27
6. Half Root	42	0.14	82	0.21	64	0.23
7. Alveolar Eruption	33	0.20	63	0.28[3]	49	0.17
8. Cusp Level	15	0.06	39	-0.07	29	0.01
9. Apical Completion	12	0.13	27	-0.01	23	-0.21

[1] Age at completion of proximal tibial epiphysis.

[2] Age at complete union of digital epiphyses.

[3] Significant at p = .05 or better.

TABLE IV

COMPARISON OF CORRELATIONS INVOLVING M_2 AND M_3 DEVELOPMENT AND PHYSICAL MATURATION

Correlations Involving	M_2[2]		M_3[2]	
	N	r	N	r
		Correlations		
Menarche and Beginning Root	63	0.34	38	0.05
and Alveolar Eruption	35	0.62	33	0.20
and Cusp Level	35	0.61	75	0.06
and Apical Completion	15	0.29	12	0.13
Tibial Union[1] and Beginning Root	101	0.27	48	0.39
and Alveolar Eruption	45	0.51	63	0.28
and Cusp Level	26	0.54	39	-0.07
and Apical Completion	28	0.34	26	-0.01
Hand Union[1] and Beginning Root	82	0.52	35	0.27
and Alveolar Eruption	30	0.57	49	0.17
and Cusp Level	17	0.52	29	0.01
and Apical Completion	20	0.34	23	-0.21

[1] See Table II.

[2] M_2 correlations average 0.3 higher than correlations involving M_3.

union (complete union of the metacarpal and digital epiphyses),[14] low correlations are again evidenced reaching not more than 0.3-0.4 in a few cases. While there is some tendency toward significant correlations between third molar development and epiphyseal union at the times of crown completion and beginning root formation, no great enthusiasm can be expressed for the rather low relationships between third molar tooth development and bodily development in general.

The failure of the mandibular third molar to show any great degree of communality with somatic and sexual maturation contrasts considerably with the picture drawn by the mandibular second molar. As shown in Table IV, the mandibular second molar is more highly correlated with various maturational events, exceeding the third molar for paired correlations by an average of 0.3 throughout. Thus, the low correlations between third molar formation and somatic and sexual maturation are not necessarily characteristic of the dentition, but rather uniquely true for the third molar tooth. This observation is further summarized graphically in Figure 4. Whether for tibial union or menarche, and whether for tooth formation or tooth movement, the third molar has less in common with bodily development than does the adjacent second molar tooth.

The fact that the third molar tooth exhibits a considerable degree of internal consistency, with early formation of this tooth heralding early completion and vice versa, naturally suggests a relationship between timing of formation on the one hand and the timing of movement on the other. This may perhaps be better seen by dividing the children into those early in cusp calcification (i.e., before the median) and late in calcification (i.e., after the median). As shown in the fifth table, there is very little question that children who are early in third molar calcification are correspondingly early in

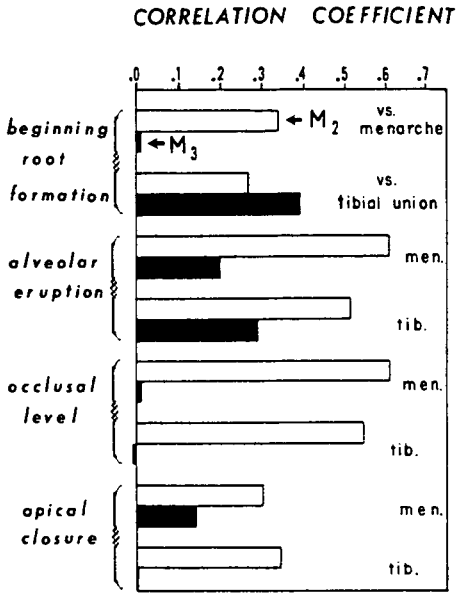

Fig. 4 Comparison of correlations involving the second and third molar, respectively. For various stages of calcification and movement, (root formation, alveolar eruption, etc.) correlations involving the mandibular second molar tend to be systematically higher than those involving the third molar.

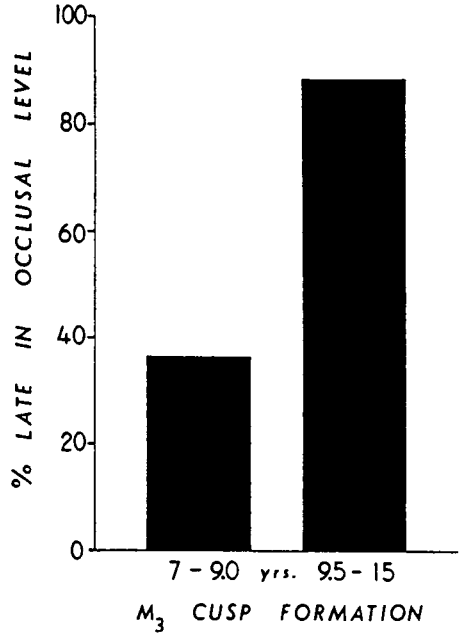

Fig. 5 Comparison of tooth movement in children early in third molar calcification (left) and late in third molar calcification (right). Children early to calcify tend to be early in their eruptive course, while late-calcifying children exhibit a tendency towards late movement of the mandibular third molar tooth.

movement through the alveolus. Moreover, the early forming children are similarly early in attaining the "occlusal" or molar cusp level (Figure 5).

Discussion

As shown in the present data, the third molar tooth seems to justify its reputation for variability in formation timing. The range of ages for each stage of formation and movement is large, being, for example, seven to fourteen years for beginning cusp calcification. Nevertheless, this is absolute

TABLE V

RELATIONSHIP BETWEEN THE TIMING OF M_3 AND THE TIMING OF M_3 MOVEMENT

M_3 Formation[1]	Alveolar Eruption		Molar Cusp Level	
	Early	Late	Early	Late
Before Median (Early)	24	13	14	8
After Median[2] (Late)	8	16	3	23

[1] Primarily cusp calcification.

[2] Including cases still unerupted after median age.

variability and due correction must be made for the fact that the variability of all developmental phenomena increases almost linearly with age.[15] Obviously, third molar cusp calcification, occurring during the eighth year on the average, may be expected to be more variable than cusp calcification of the first molar (present at one month on the average). When suitable correction is made for such age-connected variability, the third molar tooth ceases to be exceptional, being only slightly more variable overall than might be expected on the basis of the other posterior teeth.

Nevertheless, the third molar tooth is exceptional in the absence of any demonstrable sex difference in calcification and movement. All other permanent teeth are characteristically earlier in formation and eruption in the female. The eruption data, as summarized by Hurme,[17] show female advancement by amounts up to 1.3 years on the average. Our previously-analyzed data on tooth formation of P_1 - M_2 showed the sex difference clearly for all stages of all teeth considered.[10] Yet the mandibular third molar tooth evidences no difference between the sexes, a phenomenon quite in accordance with previous suggestions[4,21] and most unlikely to be due to peculiarities of the population studied.

Taken in comparison with other teeth, the mandibular third molar is unquestionably characterized by autonomy in development. True, correlations with sexual and somatic maturation are generally positive as is characteristic of dental development in general.[12] But for M_3 the correlations are of a relatively low order of magnitude, and the third molar tooth has far more independence than communality with the other teeth. In other words, the mandibular third molar tooth seems to be rather little influenced by factors that affect development of the other teeth.

This view is supported by comparisons with somatic development during the developmental period. While dental development in general is poorly related to the tempo of physical growth, the third molar tooth seems to be particularly refractory to influences (such as the caloric surplus) that accelerate physical development in general. The same appears to be true for sexual maturation. Whereas correlation between tooth formation and sexual maturation is generally higher than developmental correlations prevailing in the pre-pubertal years,[5,8] third molar tooth development tends to assert its own characteristic independence or autonomy even from sexual maturation.

But if intertooth correlations and correlations with osseous development and sexual maturation are low for the third molar, this tooth is consistent within itself, exceeding intratooth consistency previously observed for the remaining molar and premolar teeth.[8,12] Thus a child who is late in third molar calcification is similarly late in third molar movement. Children late in cusp calcification of the mandibular third molar teeth may scarcely have begun root formation when early-to-calcify children are already at the stage when the occlusal surface of that tooth is above the alveolus. Formation timing, apparently genetically determined as we have previously shown,[6,11] may thus underlie late eruption of the mandibular third molar tooth, as also suggested by data of Björk, Jensen and Palling.[2]

Speculatively, one may wonder what proportion of third molar teeth delayed in eruption or clinically impacted may be so on a genetic basis. Speculatively again, one wonders what effect the prevailing tendency toward earlier sexual maturation has had on the clinical eruption of the third molar tooth. So-

matic and sexual maturation can be accelerated by hypernutrition during the growing period,[7,20] but the third molar tooth appears to be largely independent of the rate of sexual maturation of growth-accelerating phenomena in general.

Finally, it would be extremely interesting to study the developmental course of the mandibular third molar in those populations where (as in India[22] and East Africa[3]) this tooth may evidence clinical emergence as early as the thirteenth year. Is the third molar uniquely independent, as to be years advanced in some groups and years delayed in others? Or, is this apparent advancement of the mandibular third molar merely a manifestation of early tooth formation in general?

Summary

1. Calcification and movement of the mandibular third molar was investigated in serial, longitudinal radiographs of 140 clinically-healthy, white Ohio-born children.

2. Despite very large variability in calcification and movement timing for all nine stages observed, relative or age-corrected variability was not markedly greater than for other posterior teeth.

3. Throughout its formation the mandibular third molar evidenced no significant sex difference in timing, thus being unique among the teeth.

4. Interrelationships with somatic growth and sexual maturation were low and rarely significant, thus emphasizing the developmental autonomy of the third molar tooth.

5. In contrast, the mandibular third molar showed uniquely high consistency during development even over a twelve-year period.

6. Thus, early-calcifying third molar teeth were advanced in movement through the alveolus and to the occlusal (cusp) level.

7. Attention was directed to the problem of tooth formation in populations characterized by extremely early eruption of M_3.

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